Pacific Northwest
NATIONAL LABORATORY

WILDFIRE RISK & RESILIENCE
@PNNL

Electrical Aspects of Wildland Fire Origin and Cause Investigations

Michael G. Abraham, PE, CFI, INVF
Forensic Engineer and Technical Advisor

U.S. DEPARTMENT of ENERGY BATTELLE

PNNL is operated by Battelle for the U.S. Department of Energy

PNNL-SA-226236

Why does this matter?

Wildland fires result in the loss of life and property. Major recent fire events such as the Maui Wildfires (August 2023) and Southern California Fires (January 2025) caused widespread devastation.

The origin and cause determination plays a major role in public safety by learning from the event and preventing future fires.

A major part of almost every investigation will be the electrical utility and associated infrastructure. This is especially relevant in the growing Wildland Urban Interface (WUI) where the wildland and built environment intersect.

Wildland Fire Investigations

- 2020 Babb Rd. Fire (WA)
- 2020 Silverado Fire (Southern CA)
- 2022 Coastal Fire (Southern CA)
- 2022 Mosquito Fire (CA)
- 2023 Maui Fires (HI)
  - Lahaina, Olinda, Kula, Kihei, Kaanapali
- 2025 Southern CA Fires
  - Palisades, Eaton, Hurst, Hughes
- 2025 Limassol Fire (Rep. of Cyprus)

Lahaina Wildland Fire Reports Available Online

Maui County Fire Department and ATF Origin and Cause Report

mauicounty.gov/DocumentCenter/View/149693/FI23-0012446-Lahaina-Origin-and-Cause-Report_Plus-Appendix-A-B-C-Redacted?bidId=

UL FSRI Phase One – Comprehensive Timeline Report

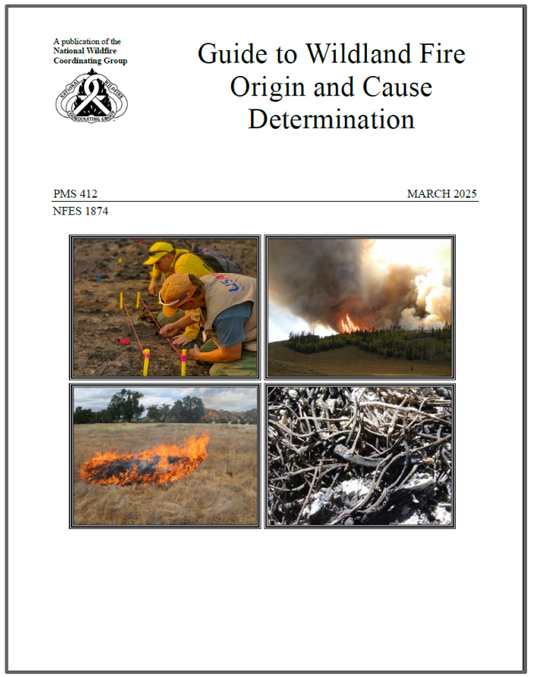
UL FSRI Phase Two – Incident Analysis Report

UL FSRI Phase Three – Forward Looking Report

https://fsri.org/research/maui-wildfires-analysis

PMS 412 (2025 Edition)

- Chapter 7 – Ignition Factors and Sources
  - Power Generation, Transmission, and Distribution Systems
    - Electrical Utility Systems
      - Ignition factors include:
        - Equipment failure
        - Failure to maintain
        - Damaged equipment
        - High-hazard areas or turbulent winds
        - High local air temperatures
        - Vegetation contact
        - Animal contact


A publication of the National Wildfire Coordinating Group

Guide to Wildland Fire Origin and Cause Determination

PMS 412 MARCH 2025

NFES 1874

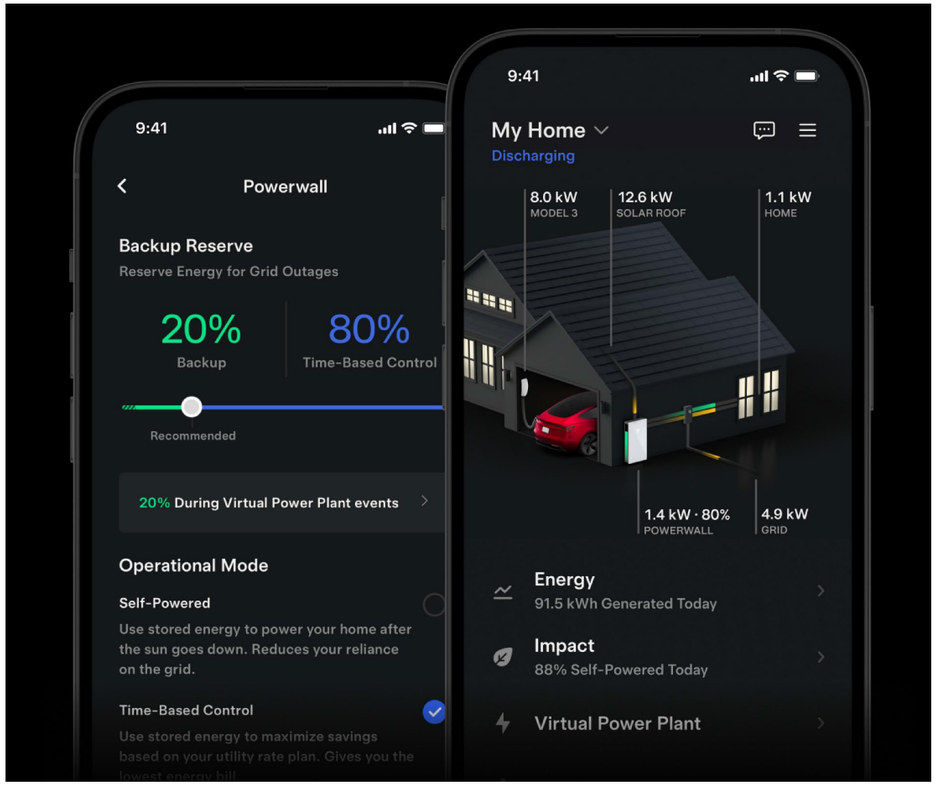
Sources of Data

Data for analysis was obtained from several sources, including but not limited to:

- MFD Record Management System (RMS) and Computer Aided Dispatch (CAD) Narratives
- Interviews, photographs, and videos documented via ATF Reports of Investigation (ROI)
- MECO produced Bates numbered data in the form of:
  - Single-line diagrams
  - Geographic Information System (GIS) maps reflecting circuit routing, pole locations, and substations
  - Supervisory Control and Data Acquisition (SCADA) system event data
  - Relay data and oscillography
  - Advanced Metering Infrastructure (AMI) system event data
  - Utility Vehicle (Asset) Global Positioning System (GPS) location data
  - Communications reporting outages and other incidents
  - FCA evidence collection and inventory documentation including photographs, video, and LiDAR scan data
- Whisker Labs produced time stamped fault data associated with Ting sensor device locations on the Island of Maui. Whisker Labs provides "…sensor technology…monitoring the resiliency…of the…electrical grid" utilizing "electromagnetic and atmospheric sensor expertise combined with AI to detect electrical faults in the home and on the grid [2]."
- ATF National Geospatial Intelligence Branch produced time-based location maps for analysis of data for the following:
  - MECO Calls (Figures 5 and 6)
  - MECO Vehicle GPS Data (Figures 7 and 8)
  - Whisker Labs Ting Sensor Fault Detection (Figure 9)
- Lightning strike data from the Worldwide Lightning Location Network (WWLLN)

The Internet of Things

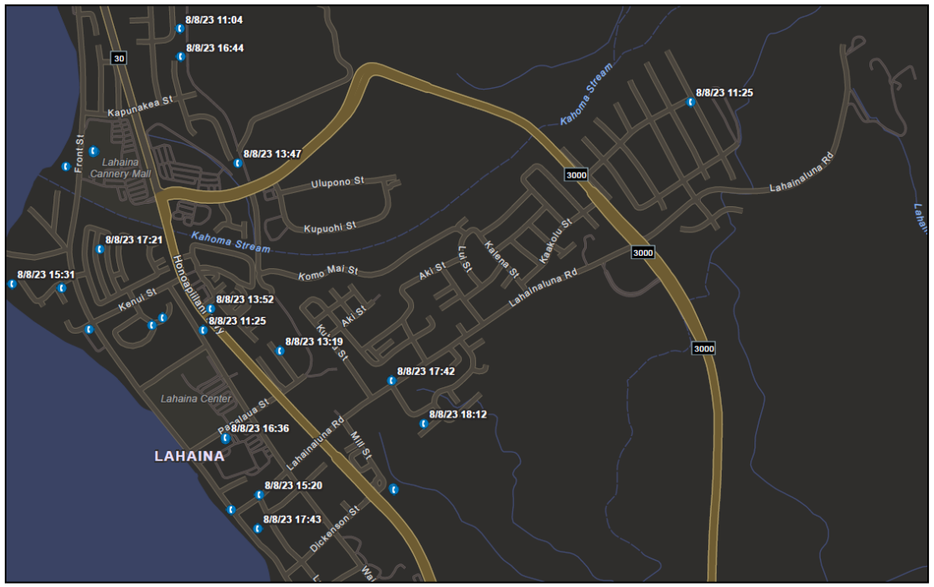
- Energy Storage
- Solar Systems
- Smart Devices



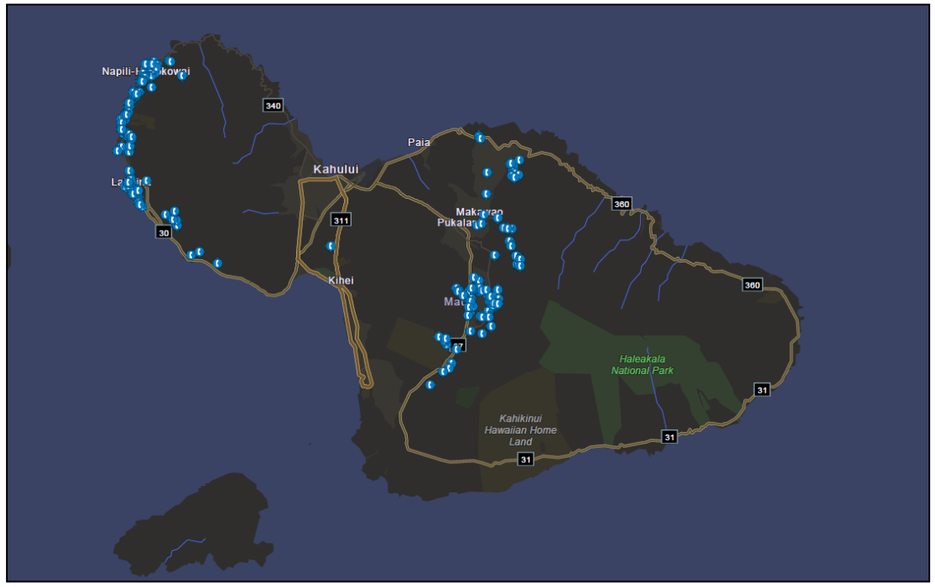
Source: https://www.tesla.com/powerwall

Utility Customer Call Mapping

Maui Wildfires NRT MECO Customer Calls Webmap

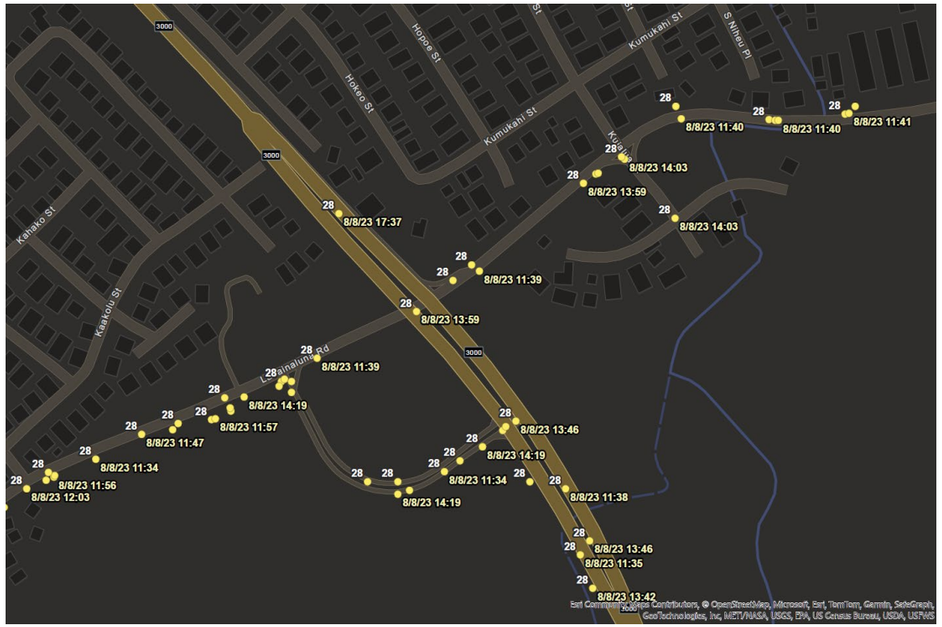


Maui Wildfires NRT MECO Customer Calls Webmap

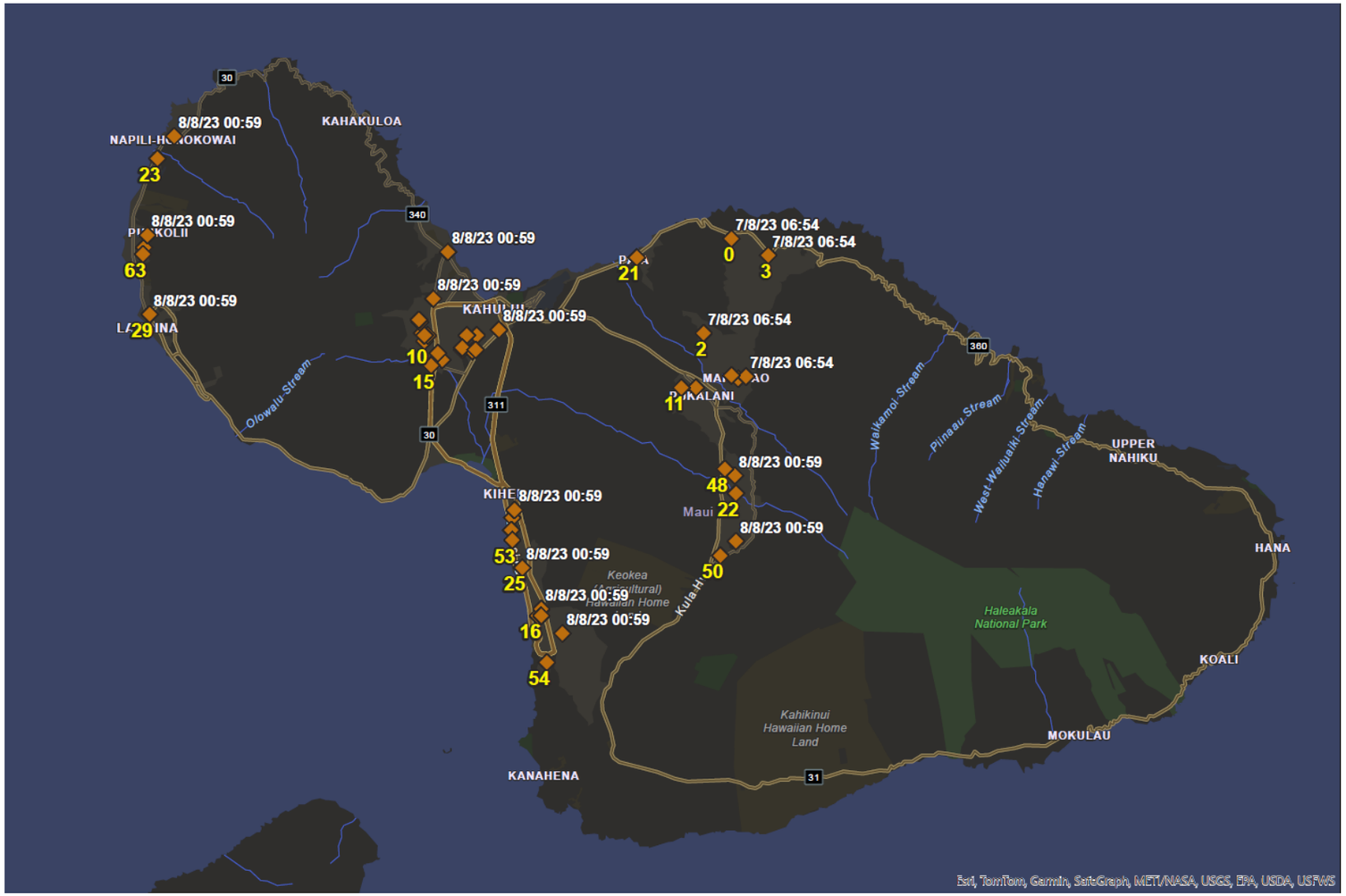


Utility Asset Mapping

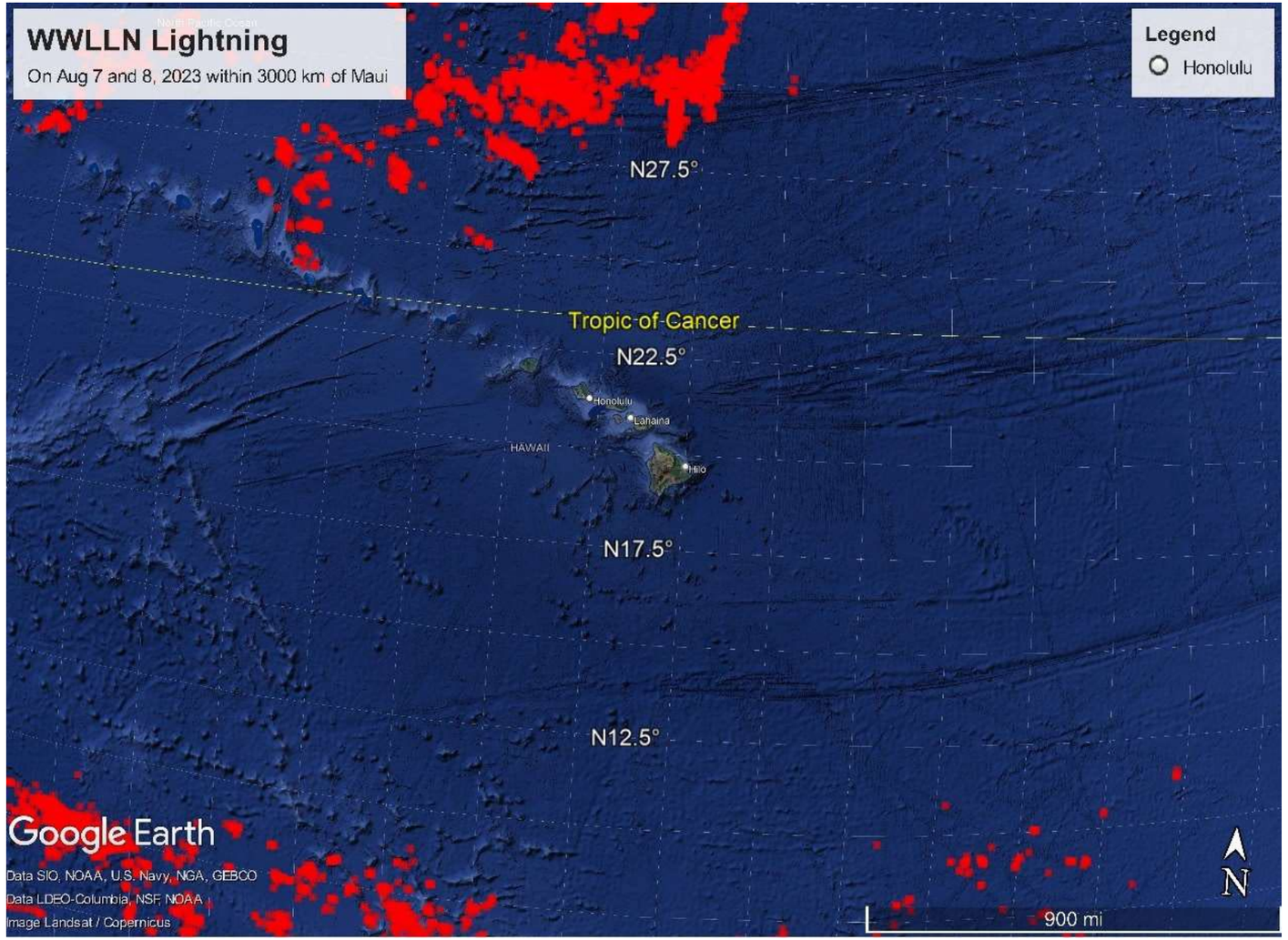
Maui Wildfires NRT MECO Asset GPS Data Webmap



Whisker Labs Ting Sensor Data



World Wide Lightning Location Network



Surveillance Video

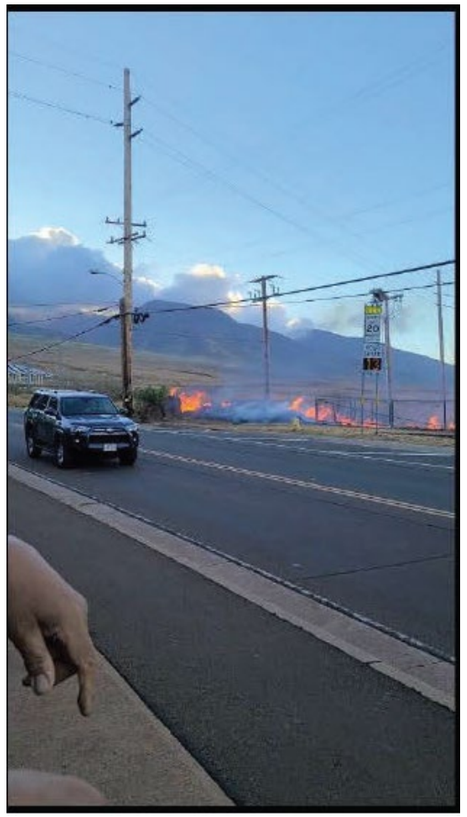
Post Fire Images at Origin

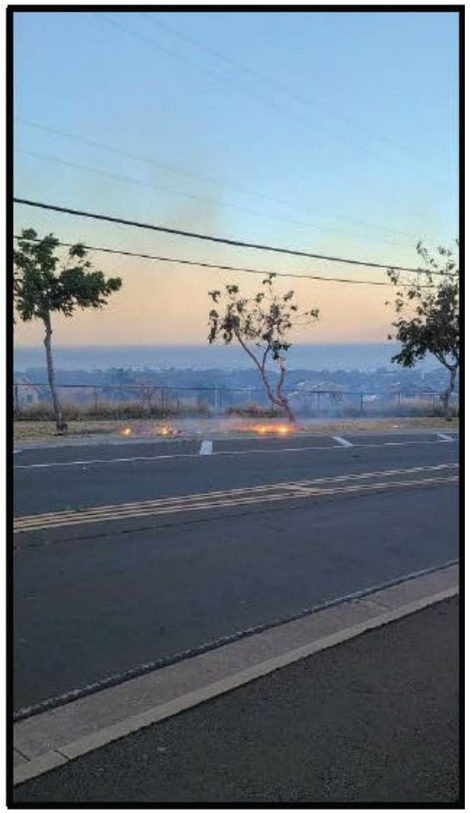





Utility Infrastructure at Origin

Eyewitness Video





Analysis of Video

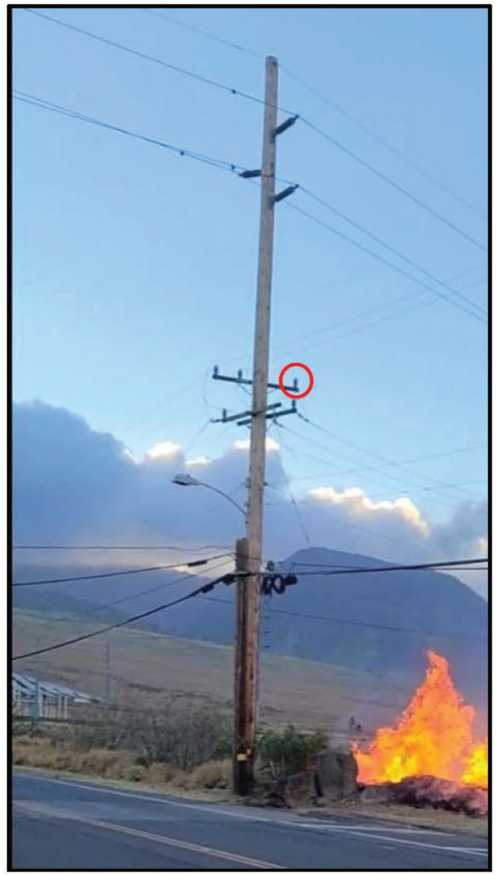


Figure 29. [redacted]_063725 Screenshot 1 (Playback time 00:01), 187721_763294 – Cropped, Zoomed, and Annotated with red circle

Figure 30. [redacted]_IMG_5228 Screenshot 1 (Playback time 00:15), 187721_763299 – Cropped, Zoomed, and Annotated with red circle

Fulgurites






Utility Substation Mapping

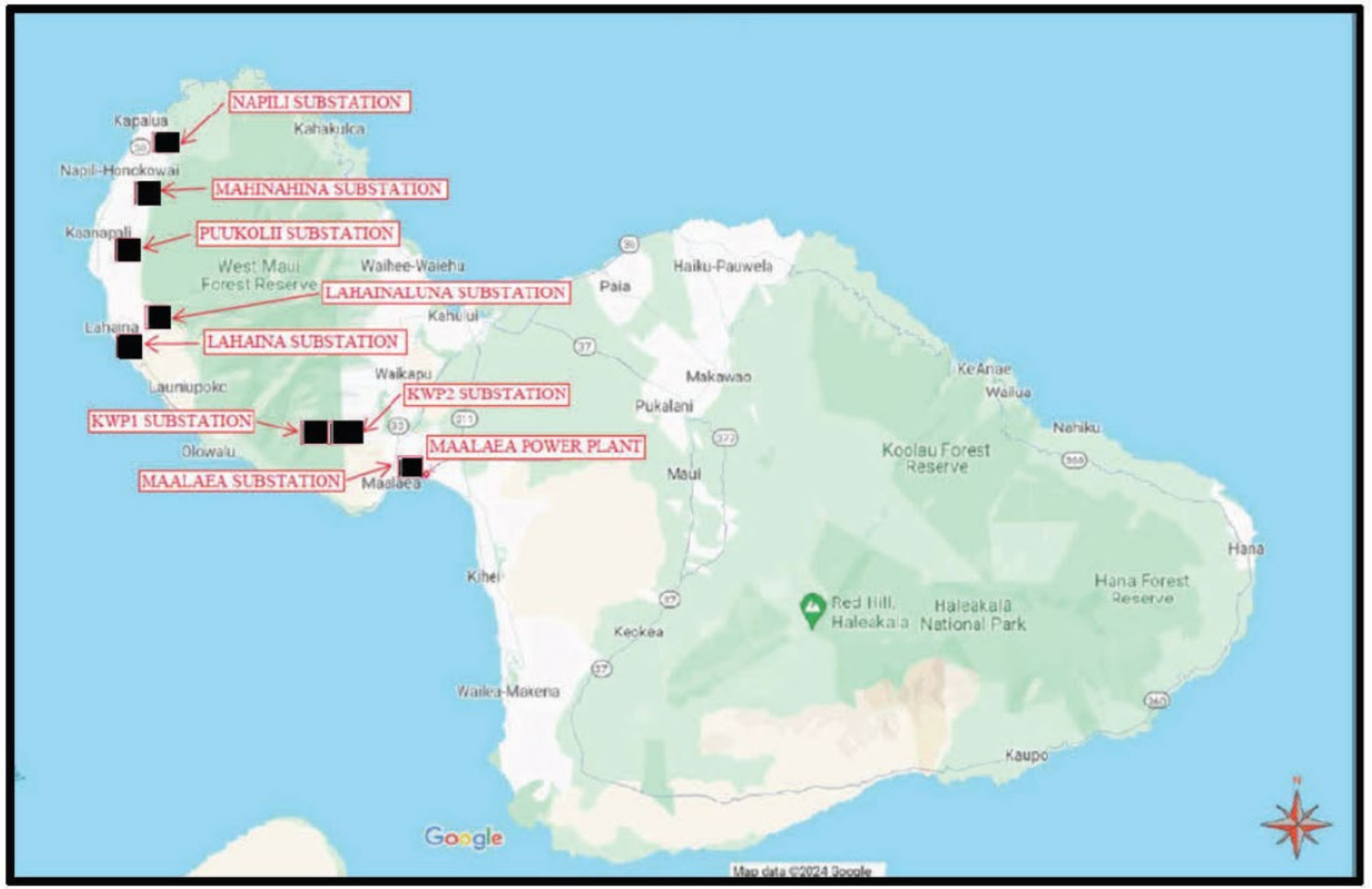


Figure 13. Lahaina Power Substation Map

System Diagram

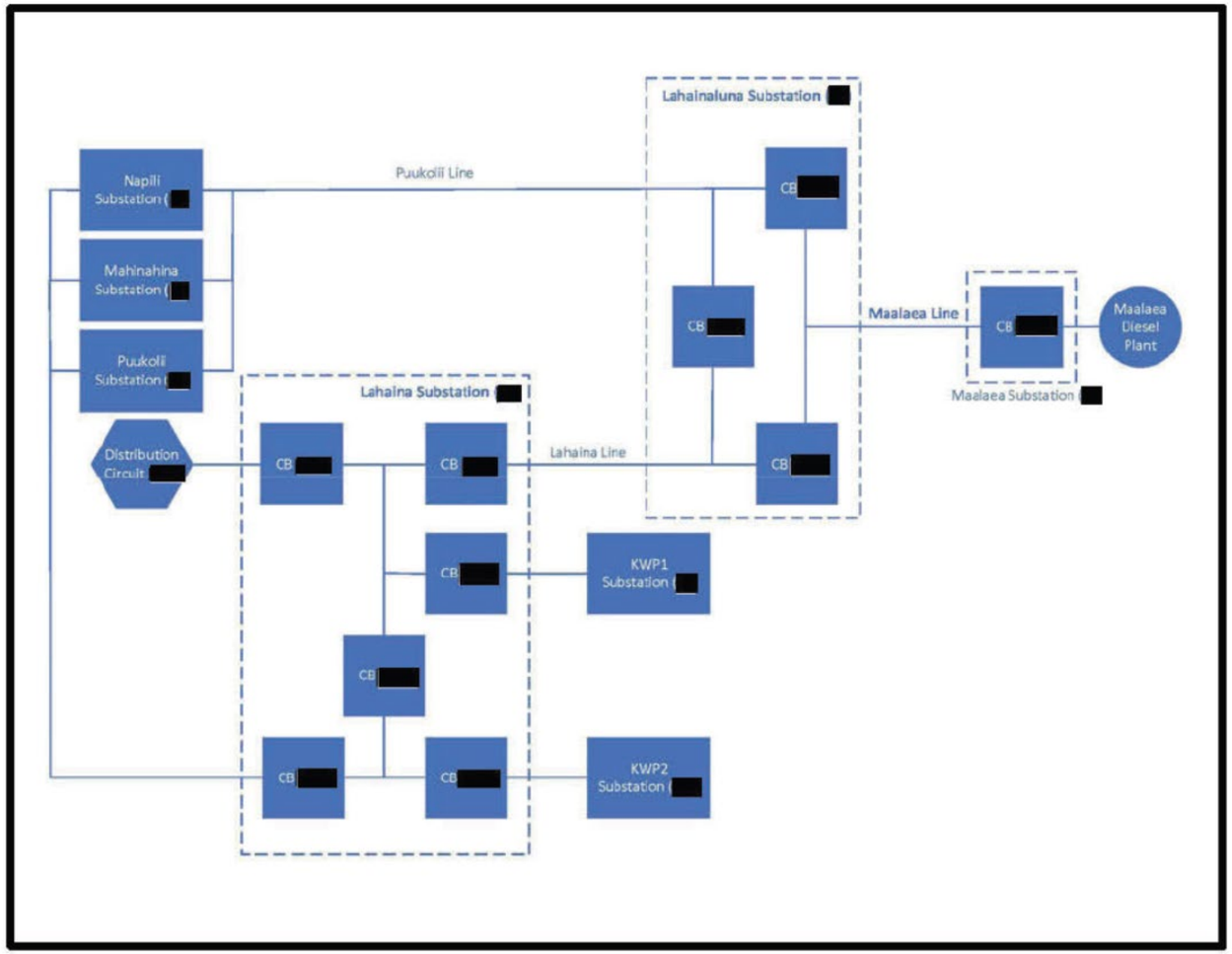


Figure 14. Lahaina Electrical System Diagram

Transmission Circuit

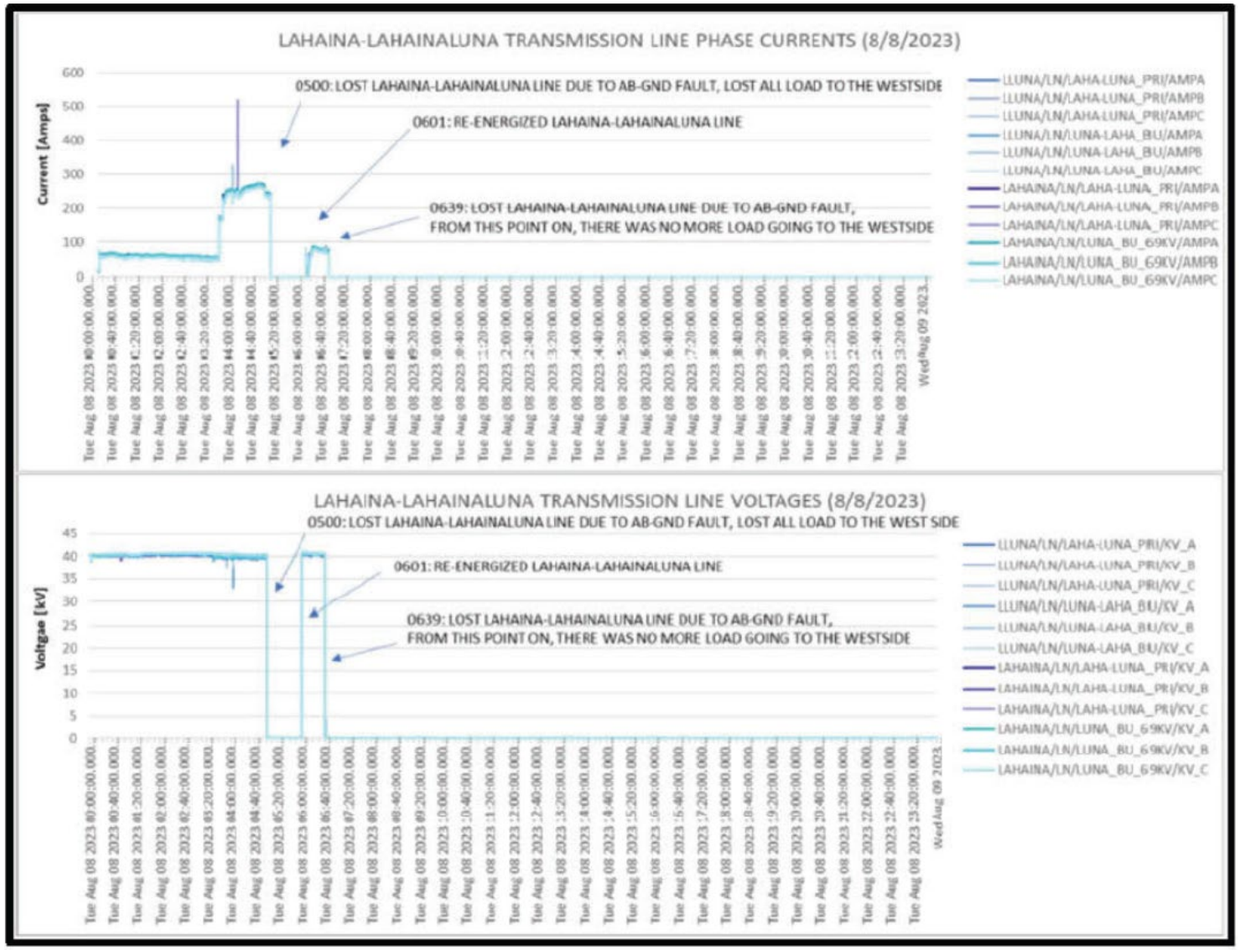


Figure 26. Lahaina Plot, MECO-ATF006 DATA-PLOT

Distribution Circuit

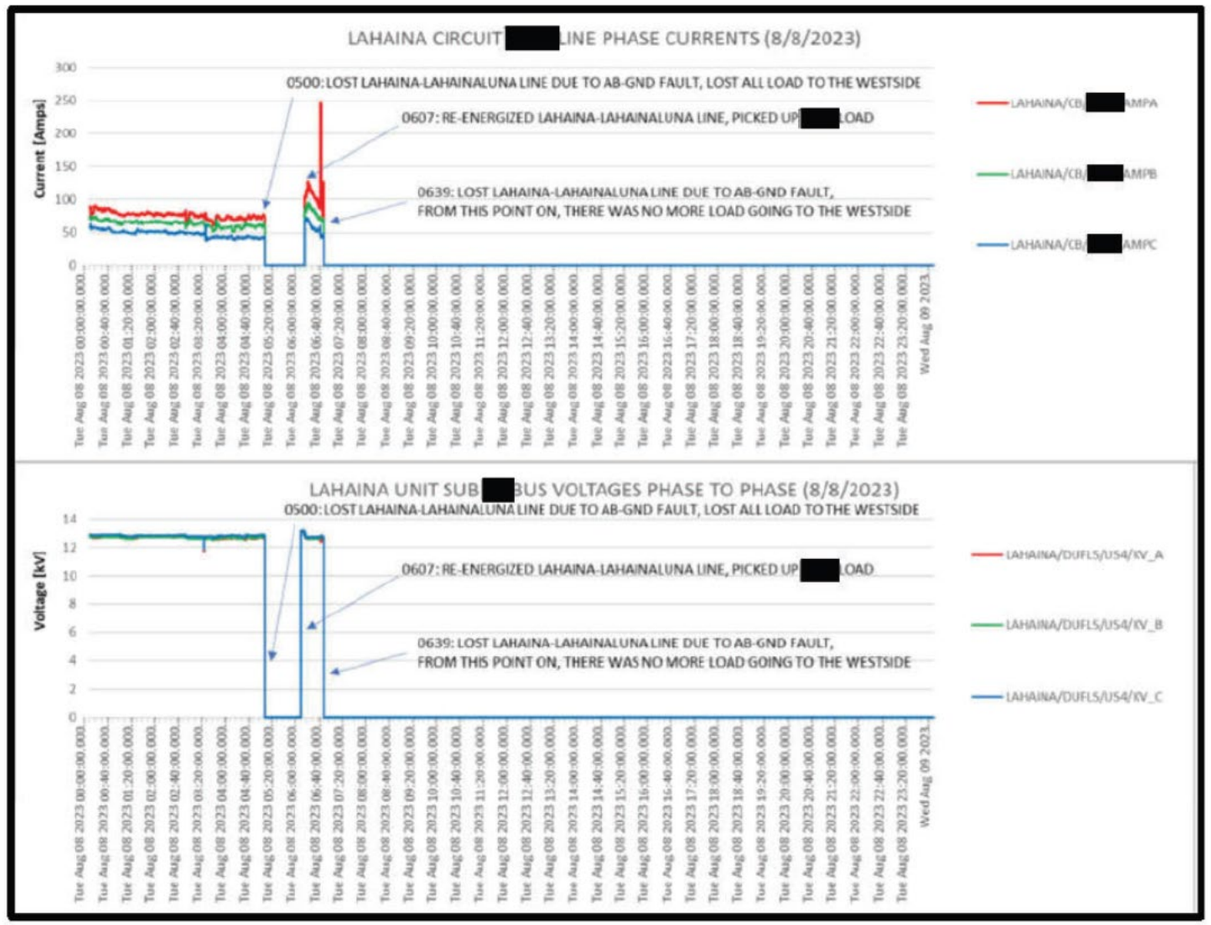
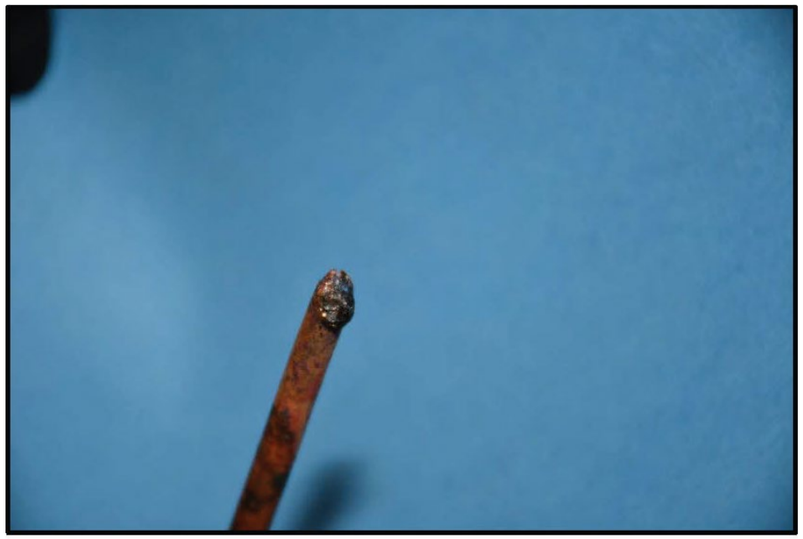
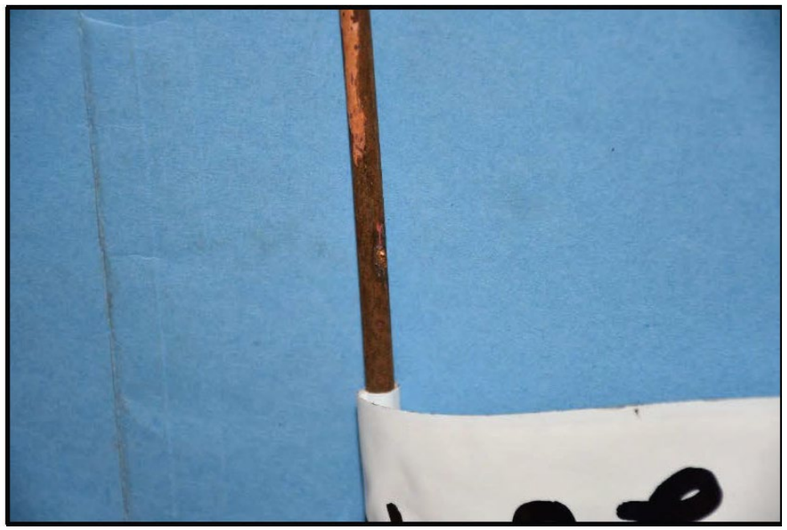


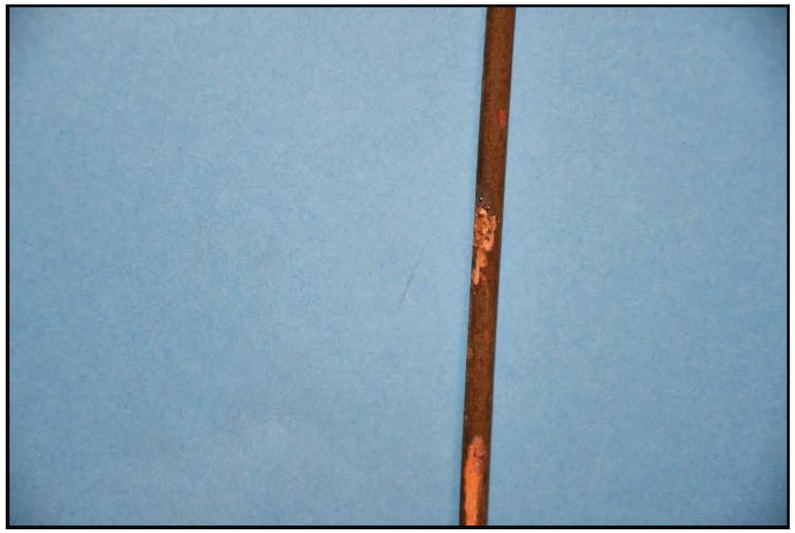
Figure 28. Distribution Circuit [redacted] Plot, MECO-ATF007 DATA-PLOT

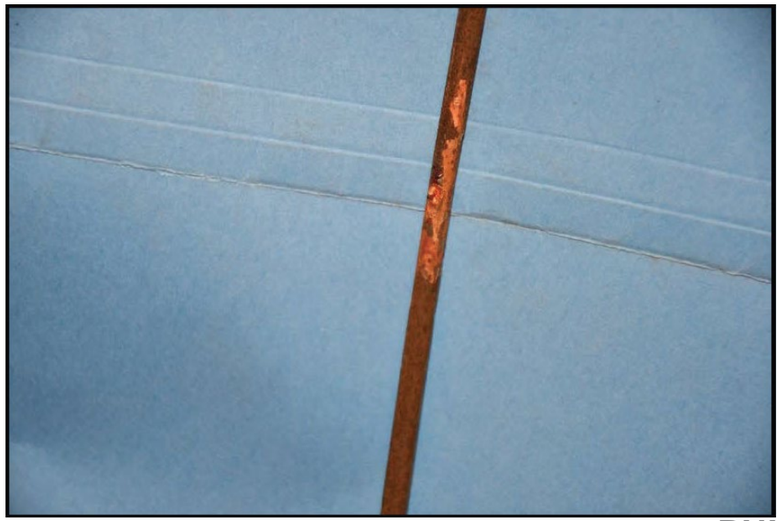
Evidence

Evidence

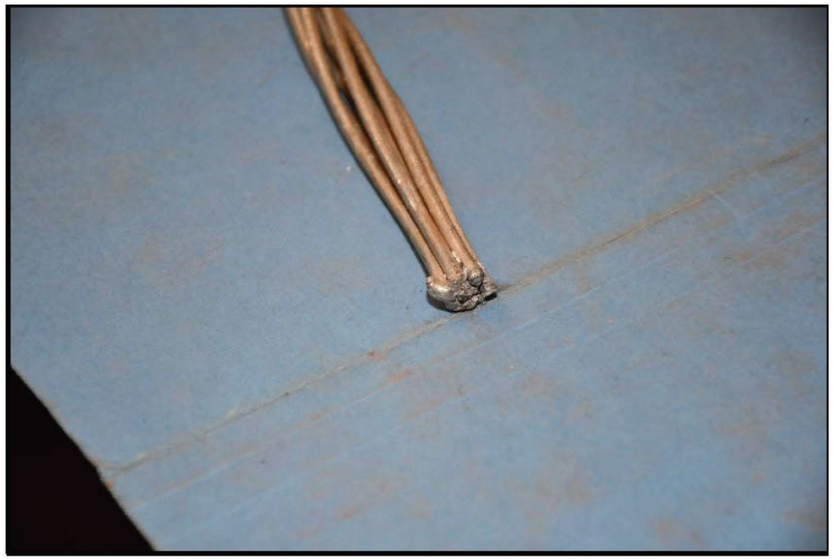








Evidence



Evidence Exam Diagram

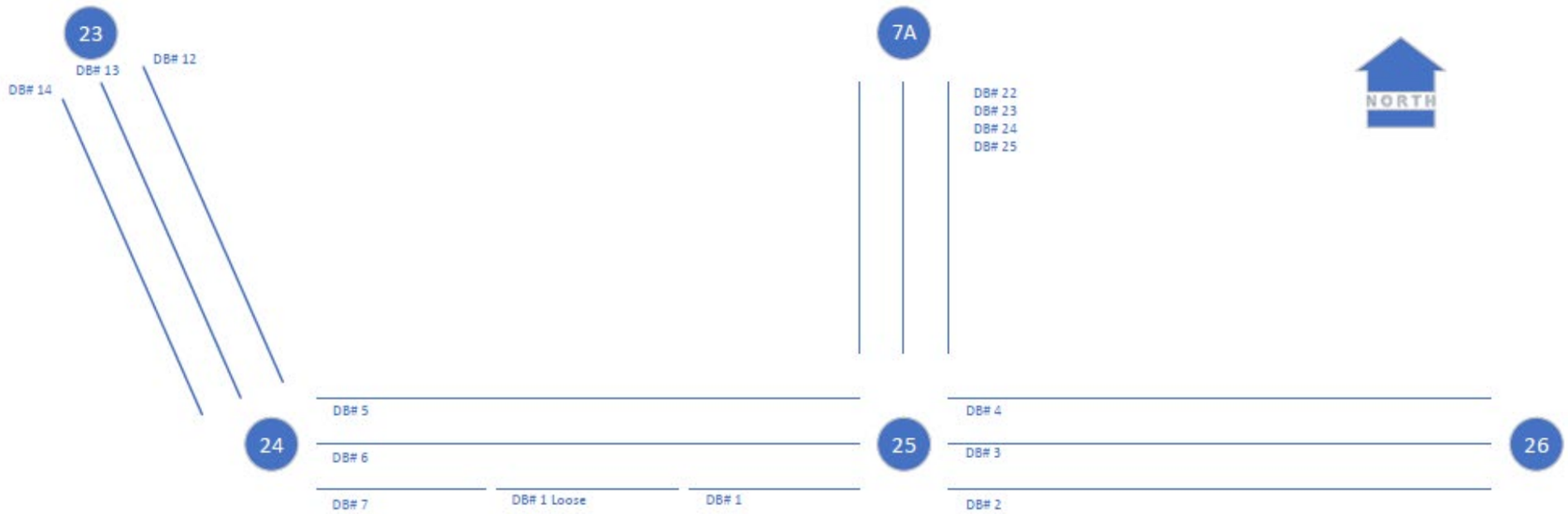


Figure 50. Exam Diagram, 187721_763730

Damaged Utility Pole

Figure 19. [redacted] photo of Lahaina Snapped Pole 7A, 187721_763291

Timeline

APPENDIX - LAHAINA ELECTRICAL TIMELINE

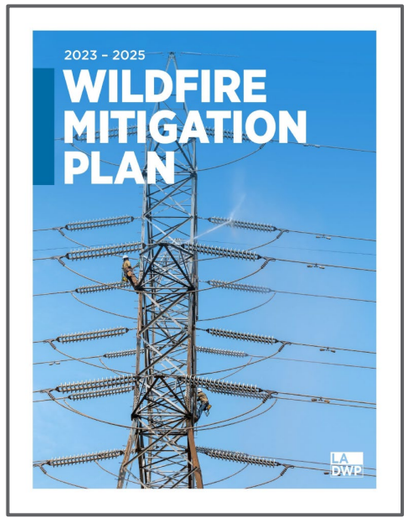
No.	TIME	CIRCUIT	EVENT	SOURCE
1	00:03:25	Lahaina Intermediate School Meter [redacted]	Sag Started Phase C	MECO-ATF-1621
2	00:53:24	Lahaina Intermediate School Meter [redacted]	Sag Stopped Phase C	MECO-ATF-1621
3	00:53:24	Lahaina Intermediate School Meter [redacted]	Sag Stopped Phase A	MECO-ATF-1621
4	01:01:58	Lahaina Intermediate School Meter [redacted]	Sag Started Phase A	MECO-ATF-1621
5	01:04:15	Lahaina Intermediate School Meter [redacted]	Sag Started Phase C	MECO-ATF-1621
6	01:28:46	Lahaina Intermediate School Meter [redacted]	Sag Stopped Phase C	MECO-ATF-1621
7	01:28:50	Lahaina Intermediate School Meter [redacted]	Sag Stopped Phase A	MECO-ATF-1621
8	02:44:30	LN LAHA-KWP2 BU 69KV (Sub [redacted] KWP2 Line)	FLTA A PHASE FAULT	MECO-ATF-1615
9	02:44:30	LAHAINA LN LAHA-KWP2 BU 69KV (Sub [redacted] KWP2 Line)	FLTC C PHASE FAULT	MECO-ATF-1615
10	02:44:30	LAHAINA LN LAHA-KWP2 BU 69KV (Sub [redacted] KWP2 Line)	TRIP TRIP	MECO-ATF-1615
11	02:44:30	LAHAINA CB [redacted]	BKR OPEN	MECO-ATF-1615
12	02:44:44	Lahaina Intermediate School Meter [redacted]	Sag Started Phase A	MECO-ATF-1621
13	02:44:45	Lahaina Intermediate School Meter [redacted]	Sag Started Phase C	MECO-ATF-1621
14	03:51:29	LAHAINA RELAY LAHA-KWP2 (Sub [redacted] KWP2 Line)	BU MBIT CHAN RLY1 ALARM	MECO-ATF-1615
15	03:30:41	LAHAINA LN LAHA-KWP1 BU 69KV (Sub [redacted] KWP1 Line)	FLTA A PHASE FAULT	MECO-ATF-1615
16	03:30:41	LAHAINA LN LAHA-KWP1 BU 69KV (Sub [redacted] KWP1 Line)	FLTG GND FAULT	MECO-ATF-1615
17	03:30:41	LAHAINA LN LAHA-KWP1 BU 69KV (Sub [redacted] KWP1 Line)	TRIP TRIP	MECO-ATF-1615
18	03:30:41	LAHAINA CB [redacted]	BKR OPEN	MECO-ATF-1615
19	03:37:30	LLUNA LN LLUNA-LAHA_PRI_69KV (Sub [redacted] Lahaina Line)	LOSP LOSS SYNC POT	MECO-ATF-1617
20	03:37:30	LLUNA CB [redacted]	BKR OPEN	MECO-ATF-1617
21	03:37:30	LLUNA CB [redacted]	BKR OPEN	MECO-ATF-1617
22	03:44:37	LLUNA LN LLUNA-LAHA_PRI_69KV (Sub [redacted] Lahaina Line)	AMPA OVERLOAD HIGH current value: 251.3 high limit: 250.0	MECO-ATF-1617
23	03:51:17	LLUNA LN LUNA-LAHA BU 69KV (Sub [redacted] Lahaina Line)	AMPB OVERLOAD HIGH current value: 250.3 high limit: 250.0	MECO-ATF-1617
24	03:51:17	LLUNA RELAY LUNA-LAHA (Sub [redacted] Lahaina Line)	PRI DIFF CHANN RLY1 ALARM	MECO-ATF-1617
25	03:51:24	LAHAINA LN LAHAINA-LLUNA PRI 69KV (Sub [redacted] To LLUNA Line)	MW OVERLOAD LOW current value: -30.1 low limit: -30.0	MECO-ATF-1615
26	04:02:27	LAHAINA LN LAHAINA-LLUNA PRI 69KV (Sub [redacted] To LLUNA Line)	MW OVERLOAD LOW current value: -30.1 low limit: -30.0	MECO-ATF-1615
27	04:03:49	LAHAINA LN LAHAINA-LLUNA PRI 69KV (Sub [redacted] To LLUNA Line)	MVAR EMERGENCY LOW current value: -25.6 low limit: -24.0	MECO-ATF-1615
28	04:03:49	LAHAINA LN LAHAINA-LLUNA PRI 69KV (Sub [redacted] To LLUNA Line)	AMPA IN SATURATION UNREASONABLE VALUE 640.5 LIMIT VALUE 600.0	MECO-ATF-1615
29	04:03:49	LAHAINA LN LAHAINA-LLUNA PRI 69KV (Sub [redacted] To LLUNA Line)	AMPC EMERGENCY HIGH current value: 519.2 high limit: 350.0	MECO-ATF-1615
30	04:03:49	LAHAINA LN LAHAINA-PUUKOLII 69KV (Sub [redacted] To Puukolii Line)	MVAR OVERLOAD HIGH current value: 25.9 high limit: 24.0	MECO-ATF-1615
31	04:03:49	LAHAINA LN LAHAINA-PUUKOLII 69KV (Sub [redacted] To Puukolii Line)	AMPA IN SATURATION UNREASONABLE VALUE 609.5 LIMIT VALUE 400.0	MECO-ATF-1615
32	04:03:49	LAHAINA LN LAHAINA-PUUKOLII 69KV (Sub [redacted] To Pukalani Line)	AMPC IN SATURATION UNREASONABLE VALUE 432.6 LIMIT VALUE 400.0	MECO-ATF-1615
33	04:04:07	[redacted] S. Niheu Street Meter [redacted]	Sag Started Phase A	MECO-ATF-1621
34	04:04:08	[redacted] S. Niheu Street Meter [redacted]	Sag Stopped Phase A	MECO-ATF-1621
35	04:50:19	Lahaina Intermediate School Meter [redacted]	Sag Stopped Phase C	MECO-ATF-1621
36	05:00:33	LLUNA CB [redacted]	BKR OPEN	MECO-ATF-1617
37	05:00:33	LAHAINA CB [redacted]	BKR OPEN	MECO-ATF-1615

Timeline

Timeline

85	06:39:50	LLUNA LN LUNA-LAHA BU 69KV (Sub [redacted] Lahaina Line)	FLTB B PHASE FAULT	MECO-ATF-1617
86	06:39:50	LLUNA LN LUNA-LAHA BU 69KV (Sub [redacted] Lahaina Line)	FLTG GND FAULT	MECO-ATF-1617
87	06:39:50	LLUNA LN LUNA-LAHA BU 69KV (Sub [redacted] Lahaina Line)	TRIP TRIP	MECO-ATF-1617
88	06:39:50	LLUNA RELAY LUNA-LAHA (Sub [redacted] Lahaina Line)	BU DIFF RELAY RLY1 ALARM	MECO-ATF-1617
89	06:39:52	LLUNA LN LLUNA-LAHA_PRI_69KV (Sub [redacted] Lahaina Line)	TRIP TRIP	MECO-ATF-1617
90	06:39:52	LLUNA RELAY LUNA-LAHA (Sub [redacted] Lahaina Line)	PRI DIFF CHANN RLY1 ALARM	MECO-ATF-1617
91	06:39:53	[redacted] S. Niheu Street Meter [redacted]	Power Down	MECO-ATF-1621
92	06:40:02	[redacted] Kuialua Street Meter [redacted]	Power Down	MECO-ATF-1621
93	06:40:08	[redacted] S. Niheu Street Meter [redacted]	Power Down	MECO-ATF-1621
94	06:40:08	[redacted] S. Niheu Street Meter [redacted]	Power Down	MECO-ATF-1621
95	06:41:00	LAHAINA CB [redacted]	BKR OPEN By [redacted]	MECO-ATF-1615
96	07:48:08	MAALAEA CB [redacted]	BKR OPEN	MECO-ATF-1617
97	15:44:11	MAALAEA CB [redacted]	BKR CLOSED By [redacted]	MECO-ATF-1617
98	19:40:27	MAALAEA CB [redacted]	BKR OPEN By [redacted]	MECO-ATF-1617

Wildland Fire Mitigation Plans



What does utility resilience mean?

- **Situational Awareness** by monitoring environmental conditions (weather stations, cameras, etc.), infrastructure data (SCADA), and historic fire data
- **Operational Practices** such as Vegetation Management, EFT, PSPS, etc. Integration with emergency management during incidents, communication during incidents, etc.
- **Grid Hardening** by upgrading infrastructure to prevent it from being the ignition source during normal or adverse conditions.
- **Partnerships** between agencies (buildings department, code enforcement, water authorities, law enforcement, fire service, forestry, etc.), and the communities they serve.

Pacific Northwest
NATIONAL LABORATORY

Thank you

Michael G. Abraham, PE, CFI, INVF
michael.abraham@pnnl.gov